PB-243 832

GULL LAKE (SOUTH BASIN), CASS AND CROW WING COUNTIES, MINNESOTA

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center

July 1975

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PB 243 832

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

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and

NATIONAL ENVIRONMENTAL RESEARCH CENTER - LAS VEGAS, NEVADA

☆GPO—697-032

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO. PB243832
4. TITLE AND SUBTITLE Report on Gull Lake (South Basin), Cass and Crow Wing Counties, Minnesota		5. REPORT DATE Prepared July 1975 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Anonymous (National Eutrophication Survey Staff)		8. PERFORMING ORGANIZATION REPORT NO. Working Paper # 102
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Eutrophication Survey U.S. Environmental Protection Agency 200 S. W. 35th St. Corvallis, Oregon 97330		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U.S. Environmental Protection Agency 401 M Street, S. W. Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED Final - 1972 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

18. DISTRIBUTION STATEMENT Release unlimited	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 34
	20. SECURITY CLASS *(This page)*	22. PRICE 3.75 - 2.25

EPA Form 2220-1 (9-73)

224073

Report

on

Gull Lake (South Basin)

Cass and Crow Wing Counties

Minnesota

EPA Region V

Working Paper No. 102

With the cooperation of the

Minnesota Pollution Control Agency

and the

Minnesota National Guard

July, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Minnesota Pollution Control Agency for professional involvement and to the Minnesota National Guard for conducting the tributary sampling phase of the Survey.

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

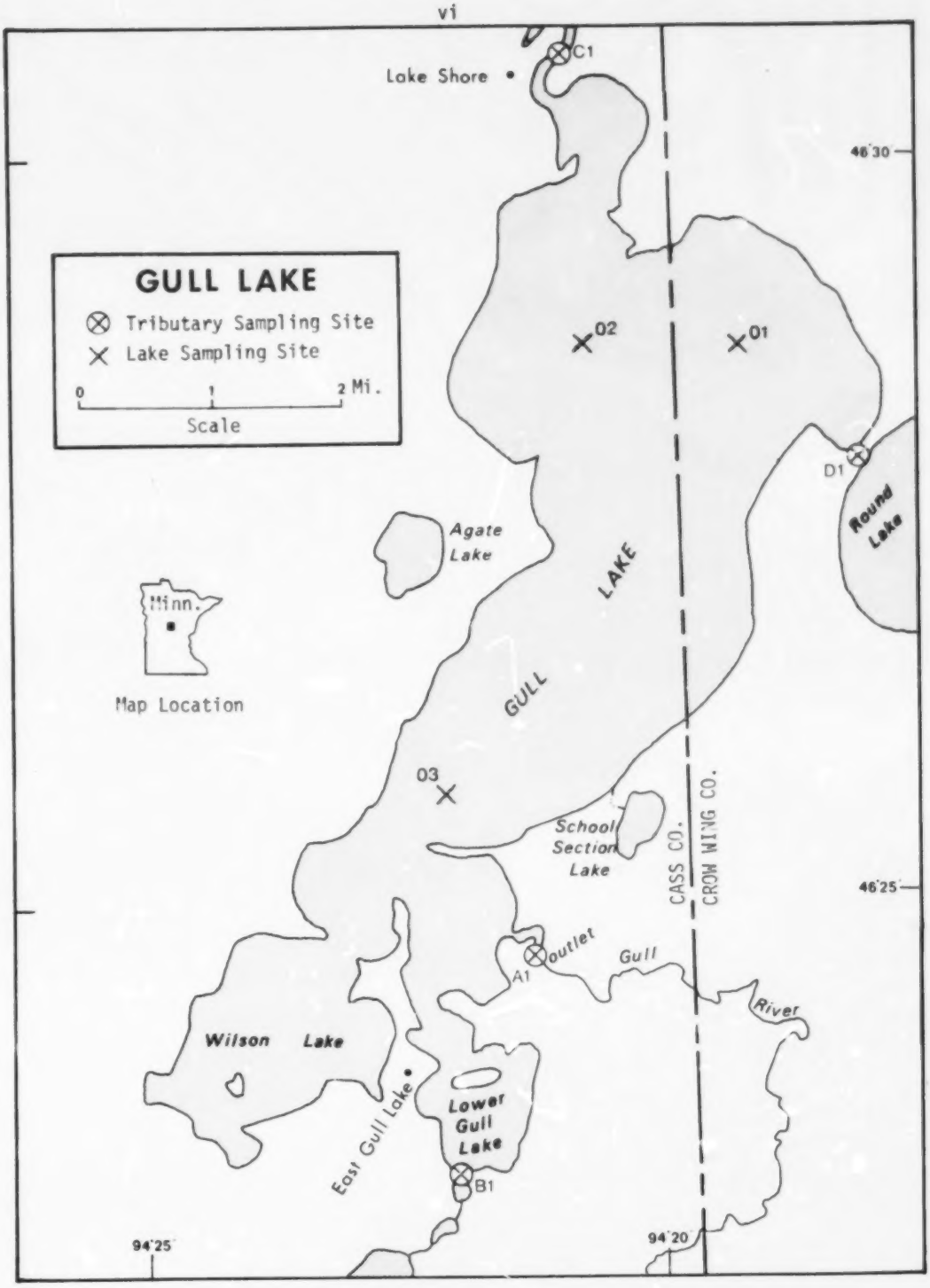
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fall	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


GULL LAKE
Tributary Sampling Site
Lake Sampling Site
0
1
2 Mi.
Scale
Lake Shore
C1
46°30
02
01
D1
Round Lake
Agate Lake
GULL LAKE
Minn.
Map Location
03
School Section Lake
CASS CO.
CROW WING CO.
46°25
A1
Outlet
Gull
River
Wilson Lake
East Gull Lake
Lower Gull Lake
B1
94°25
94°20

GULL LAKE (SOUTH BASIN)

STORET NO. 2737

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that the south basin of Gull Lake is eutrophic. Of the 60 Minnesota lakes on which sampling was completed, 18 had less and one the same mean total phosphorus, 27 had less and one the same mean dissolved phosphorus, 23 had less mean inorganic nitrogen, 27 had less and one the same mean chlorophyll a, but only eight had greater mean Secchi disc transparency. Hypolimnetic dissolved oxygen was markedly depressed at all three sampling stations in July and was depleted or nearly so below 30 feet in depth in September, 1972.

While phytoplankton numbers were not exceptionally high, blue-green algae were prominent in all samples.

B. Rate-Limiting Nutrient:

The algal assay results indicate Gull Lake was nitrogen limited at the time the sample was taken (10/24/72). The lake data also indicate nitrogen limitation at that time but indicate phosphorus limitation in July and September.

C. Nutrient Controllability:

1. Point sources--There were no known municipal wastewater treatment plants impacting Gull Lake during the sampling year.

The Village of Pequot Lakes, about 8 miles north of Gull Lake, is served by stabilization ponds, but there is no discharge from the system (Schilling, 1975).

Septic tanks serving shoreline dwellings were estimated to have contributed about 4% of the total phosphorus load to the lake, but a shoreline survey would be necessary to determine the actual significance of these sources.

It is calculated that Gull Lake received a total phosphorus load at a rate less than that proposed by Vollenweider (in press) as an oligotrophic rate (see page 12). However, the existing trophic condition of the lake indicates that either the loading rate must have been higher in the past or the true loading rate was not determined by Survey sampling. It seems more likely that the latter is the case, and a need for further study of the lake is indicated.

2. Non-point sources--Survey data indicate that upper Gull Lake contributed nearly 51% of the total annual phosphorus load to the south basin of Gull Lake. The origin of the phosphorus load from upper Gull Lake is not known; but if the load could be significantly reduced, it is believed the water quality of the south basin of Gull Lake would be improved.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 9,540 acres.
2. Mean depth: 30 feet.
3. Maximum depth: 86 feet.
4. Volume: 286,200 acre-feet.
5. Mean hydraulic retention time: 2.9 years.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area (mi^2)*	Mean flow (cfs)*
Dade Lake connection	8.5	3.7
Upper Gull Lake connection	200.0	98.2
Round Lake connection	52.6	19.9
Minor tributaries & immediate drainage -	20.0	13.0
Totals	281.1	134.8

2. Outlet -

Gull River	296.0**	134.9

C. Precipitation***:

1. Year of sampling: 32.7 inches.
2. Mean annual: 27.5 inches.

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† Affeldt, 1971.
* Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Gull Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake and from a number of depths at each station (see map, page vi). During each visit, a single depth-integrated (15 feet to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the last visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected at each of the stations for chlorophyll a analysis. The maximum depths sampled were 60 feet at station 1, 40 feet at station 2, and 66 feet at station 3.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized in the following table. Note, however, the Secchi disc summary is based on all samples.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (10/24/72)		
Temperature (Cent.)	7.3	7.6	7.7	7.8
Dissolved oxygen (mg/l)	9.4	10.6	10.2	12.4
Conductivity (μmhos)	208	214	212	220
pH (units)	7.7	7.8	7.8	7.9
Alkalinity (mg/l)	99	105	105	107
Total P (mg/l)	0.017	0.034	0.037	0.052
Dissolved P (mg/l)	0.010	0.024	0.027	0.036
NO_2 + NO_3 (mg/l)	0.030	0.040	0.040	0.050
Ammonia (mg/l)	0.110	0.120	0.120	0.160
		ALL VALUES		
Secchi disc (inches)	77	91	84	120

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
07/02/72	1. Tabellaria	1,392
	2. Microcystis	958
	3. Fragilaria	416
	4. Oocystis	307
	5. Flagellates	271
	Other genera	688
	Total	4,032
09/05/72	1. Microcystis	714
	2. Anabaena	542
	3. Dinobryon	443
	4. Lyngbya	344
	5. Aphanocapsa	316
	Other genera	498
	Total	2,857
10/24/72	1. Flagellates	2,906
	2. Dinobryon	1,358
	3. Fragilaria	981
	4. Anabaena	868
	5. Chroococcus	490
	Other genera	2,831
	Total	9,434

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (μg/l)
07/02/72	01	17.6
	02	13.1
	03	10.2
09/05/72	01	8.3
	02	4.8
	03	8.8
10/24/72	01	19.1
	02	16.3
	03	14.0

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.029	0.131	2.4
0.005 P	0.034	0.131	2.3
0.010 P	0.039	0.131	2.5
0.020 P	0.049	0.131	2.6
0.050 P	0.079	0.131	2.7
0.050 P + 10.0 N	0.079	10.131	29.5
10.0 N	0.029	10.131	5.4

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Lower Gull Lake was moderate at the time of sampling (10/24/72). Also, the results indicate the lake was nitrogen

limited at that time. No growth response accompanied spikes of phosphorus alone, but the addition of nitrogen alone stimulated growth significantly.

The lake data substantiate nitrogen limitation at the time of assay sample collection (the N/P ratio was 6/1) but indicate phosphorus limitation in July (N/P = 16/1) and September (N/P = 16/1).

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Minnesota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of April and May when two samples were collected. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Minnesota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated from mean annual concentrations and mean annual flows. Nutrient loadings for "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient concentrations in the Dade Lake connection (station B-1) and the Round Lake connection (station D-1) and the mean annual ZZ flow.

A. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Dade Lake connection	120	1.5
Upper Gull Lake connection	5,220	64.5
Round Lake connection	550	6.8
b. Minor tributaries & immediate drainage (non-point load) -	380	4.7
c. Known municipal STP's - None	-	-
d. Septic tanks* -	330	4.1
e. Known industrial - None	-	-
f. Direct precipitation** -	1,490	18.4
Total	8,090	100.0

2. Outputs -

Lake outlet - Gull River 5,050

3. Net annual P accumulation - 3,040 pounds

* Estimate based on 285 lakeshore dwellings and 25 resorts (Affeldt, 1971); see Working Paper No. 1.
** See Working Paper No. 1.

B. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Dade Lake connection	5,670	1.8
Upper Gull Lake connection	158,720	50.7
Round Lake connection	25,780	8.2
b. Minor tributaries & immediate drainage (non-point load) -	18,380	5.9
c. Known municipal STP's - None	-	-
d. Septic tanks* -	12,570	4.0
e. Known industrial - None	-	-
f. Direct precipitation** -	91,910	29.4
Total	313,030	100.0

2. Outputs -

Lake outlet - Gull River 193,070

3. Net annual N accumulation - 119,960 pounds

* Estimate based on 285 lakeshore dwellings and 25 resorts (Affeldt, 1971); see Working Paper No. 1.

** See Working Paper No. 1.

C. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
Dade Lake connection	14	667
Upper Gull Lake connection	26	794
Round Lake connection	10	490

D. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
lbs/acre/yr	0.85	0.32	32.8	12.6
grams/m^2/yr	0.10	0.04	3.7	1.4

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of Gull Lake:

"Dangerous" (eutrophic rate)	0.34
"Permissible" (oligotrophic rate)	0.17

V. LITERATURE REVIEWED

Affeldt, Craig, 1971. Report on investigation of water quality of the Gull Lake Chain, Cass and Crow Wing Counties. MPCA, Minneapolis.

Schilling, Joel, 1975. Personal communication (Pequot Lakes wastewater treatment system). MPCA, Minneapolis.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

VI APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2737 GULL LAKE

TOTAL DRAINAGE AREA OF LAKE 296.00

NORMALIZED FLOWS

TRIBUTARY	SUB-DRAINAGE AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2737A1	296.00	125.20	123.80	131.90	197.20	186.70	189.40	129.00	91.50	97.60	106.30	108.90	131.90	134.90
2737B1	8.50	1.26	1.69	2.26	5.97	5.65	5.26	3.69	3.36	3.02	5.90	4.07	2.61	3.74
2737C1	200.00	66.50	98.00	83.60	162.00	148.00	129.00	93.40	94.50	65.00	140.00	11.40	86.80	98.25
2737D1	52.60	4.33	6.39	10.30	39.60	33.80	32.80	22.10	17.80	14.40	26.50	20.00	10.00	19.87
2737ZZ	35.20	5.30	7.18	8.71	24.90	20.30	21.80	13.10	10.30	9.07	15.70	11.30	8.68	13.04

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 296.00
SUM OF SUB-DRAINAGE AREAS = 296.30

TOTAL FLOW IN = 1617.30
TOTAL FLOW OUT = 1619.40

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2737A1	10	72	111.00	15	80.00				
	11	72	359.00	18	370.00				
	12	72	194.00	22	177.00				
	1	73	162.00	6	320.00				
	2	73	99.00	4	120.00				
	3	73	163.00	26	165.00				
	4	73	101.00	9	75.00	24	180.00		
	5	73	234.00	4	250.00	20	100.00		
	6	73	97.00	11	180.00				
	7	73	162.00	13	100.00				
	8	73	218.00	17	340.00				
	9	73	94.90	17	40.00				
2737B1	10	72	3.25	15	3.30				
	11	72	5.17	18	4.80				
	12	72	3.14	22	3.10				
	1	73	2.21	6	2.20				
	2	73	1.66	4	1.70				
	3	73	6.78	26	8.80				
	4	73	4.98	9	4.70	24	5.80		
	5	73	6.30	4	6.30	20	5.60		
	6	73	4.50	11	4.90				
	7	73	3.91	13	3.80				
	8	73	1.68	17	1.80				
	9	73	2.36	17	2.20				

15.

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2737 GULL LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2737C1	10	72	77.20	15	79.00				
	11	72	145.00	18	135.00				
	12	72	105.00	22	105.00				
	1	73	115.00	6	117.00				
	2	73	46.00	4	101.00				
	3	73	251.30	26	326.00				
	4	73	135.00	9	128.00	24	157.00		
	5	73	165.00	4	165.00	20	147.00		
	6	73	110.00	11	120.00				
	7	73	99.30	13	97.00				
	8	73	47.20	17	50.00				
	9	73	59.70	17	47.00				
273701	10	72	14.00	15	15.00				
	11	72	25.40	18	24.00				
	12	72	12.00	22	12.00				
	1	73	7.55	6	7.60				
	2	73	6.26	4	6.60				
	3	73	30.40	26	40.00				
	4	73	33.00	9	31.00	24	38.00		
	5	73	37.00	4	38.00	20	34.00		
	6	73	28.10	11	31.00				
	7	73	23.40	13	23.00				
	8	73	9.30	17	9.40				
	9	73	11.20	17	10.00				
273777	10	72	5.67	15	5.80				
	11	72	14.40	18	13.00				
	12	72	10.50	22	10.00				
	1	73	9.25	6	9.30				
	2	73	7.03	4	7.40				
	3	73	26.10	26	34.00				
	4	73	20.70	9	19.00	24	24.00		
	5	73	22.60	4	23.00	20	20.00		
	6	73	18.60	11	20.00				
	7	73	13.90	13	14.00				
	8	73	5.15	17	5.50				
	9	73	7.07	17	6.60				

16.

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/10/30

273701
46 28 42.0 094 19 12.0
GULL LAKE
27 MINNESOTA

11EPALES
3 2111202
0060 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/02	11 05	0000	21.0	8.2	120	190	8.50	100	0.040	0.040	0.022	0.009
	11 05	0015	17.5	8.2		195	7.90	101	0.040	0.040	0.022	0.009
	11 05	0030	11.5	4.3		205	7.30	104	0.160	0.040	0.014	0.010
	11 05	0060	8.0	1.0		210	7.00	118	0.300	0.160	0.049	0.029
72/09/05	13 27	0000	18.8		108	195	8.55	95	0.050	0.070	0.013	0.008
	13 27	0004	18.8	8.5		190	8.55	93	0.040	0.060	0.013	0.007
	13 27	0015	18.4	8.0		190	8.55	94	0.040	0.050	0.011	0.007
	13 27	0030	17.4	6.4		195	8.15	119	0.040	0.050	0.011	0.007
	13 27	0045	11.3	0.4		218	7.30	123	0.050	0.240	0.045	0.013
72/10/24	13 30	0000			77	210	7.80	106	0.040	0.120	0.017	0.010
	13 30	0004	7.7	9.9		208	7.80	105	0.040	0.120	0.034	0.025
	13 30	0015	7.7	10.2		208	7.80	107	0.040	0.120	0.043	0.029
	13 30	0025	7.5	10.2		210	7.80	107	0.040	0.120	0.041	0.030
	13 30	0035	7.3	9.4		208	7.70	107	0.040	0.120	0.044	0.032
	13 30	0046	7.5	10.0		212	7.70	107	0.040	0.120	0.052	0.036

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/02	11 05	0000	17.6J
72/09/05	13 27	0000	8.3J
72/10/24	13 30	0000	19.1J

J VALUE KNOWN TO BE IN ERROR

181

STORET RETRIEVAL DATE 74/10/30

273702
46 28 48.0 094 20 36.0
GULL LAKE
27 MINNESOTA

11EPALES
3

2111202
0045 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/02	11 30	0000	21.0	7.8	84	190		99	0.050	0.040	0.020	0.010
	11 30	0024	15.0	7.0		200		104	0.060	0.050	0.023	0.010
	11 30	0040	9.5	1.2		205		104	0.260	0.080	0.154	0.012
72/09/05	13 03	0000	18.5		96	190	8.50	112	0.040	0.060	0.018	0.010
	13 03	0004	18.5	8.5		187	8.50	112	0.040	0.040	0.017	0.008
	13 03	0015	18.0	7.6		190	8.40	110	0.040	0.050	0.012	0.008
	13 03	0030	17.8	6.6		195	8.30	111	0.040	0.050	0.013	0.007
72/10/24	14 05	0000			78	220	7.90	105	0.040	0.110	0.017	0.011
	14 05	0004	7.6	12.4		212	7.90	106	0.040	0.110	0.034	0.023
	14 05	0015	7.6	11.0		218	7.90	105	0.040	0.110	0.030	0.022

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/02	11 30	0000	13.1J
72/09/05	13 03	0000	4.8J
72/10/24	14 05	0000	16.3J

J VALUE KNOWN TO BE IN ERROR

19

STORET RETRIEVAL DATE 74/10/30

273703
46 25 42.0 094 21 57.0
GULL LAKE
27 MINNESOTA

11EPALES 2111202
3 0050 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/02	12 00	0000	21.5	8.8	78	195	8.40	98	0.040	0.050	0.015	0.010
	12 00	0015	21.0	8.6				107	0.040	0.060	0.026	0.015
	12 00	0040	9.0	1.8		210	7.20	107	0.310	0.040	0.015	0.011
72/09/05	11 55	0000	18.2		96	190	8.40	108	0.050	0.120	0.014	0.011
	11 55	0004	18.2	6.7		190	8.45	108	0.040	0.050	0.014	0.008
	11 55	0015	17.9	8.0		185	8.40	108	0.050	0.050	0.014	0.007
	11 55	0030	16.3	3.1		215	7.30	118	0.030	0.050	0.013	0.009
	11 55	0045	11.1	0.4		220	7.20	119	0.030	0.270	0.040	0.031
	11 55	0066	9.7	0.0		200	7.50	119	0.070	0.850	0.082	0.020
72/10/24	14 30	0000			84	220	7.80	99	0.040	0.120	0.019	0.011
	14 30	0004	7.8	10.3		212	7.80	99	0.040	0.110	0.032	0.023
	14 30	0015	7.7	9.9		220	7.80	99	0.030	0.110	0.036	0.027
	14 30	0025	7.7	9.9		210	7.80	105	0.040	0.130	0.037	0.025
	14 30	0035	7.7	10.2		210	7.80					
	14 30	0045	7.7	10.3		212	7.80	105	0.040	0.130	0.041	0.028
	14 30	0055	7.7	9.6		220	7.80	105	0.040	0.140	0.037	0.028
	14 30	0062	7.7	10.4		220	7.70	106	0.050	0.160	0.047	0.035

20.

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/02	12 00	0000	10.2J
72/09/05	11 55	0000	8.8J
72/10/24	14 30	0000	14.0J

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY DATA

STORET RETRIEVAL DATE 74/10/30

2737A1 LS2737A1
46 25 00.0 094 21 30.0
GULL RIVER
27 CO #11, SHEET #1
0/GULL LAKE (CASS CO)
CO HWY 105 BRDG N OF EAST GULL LAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	10	50	0.026	0.450	0.044	0.005K	0.019
72/11/18	14	00	0.020	0.540	0.019	0.005K	0.018
72/12/22	09	40	0.035	0.560	0.034	0.005K	0.013
73/01/06	09	15	0.037	0.580	0.058	0.005K	0.020
73/02/04	10	00	0.048	0.690	0.039	0.005K	0.010
73/03/26	14	45	0.072	1.050	0.050	0.015	0.020
73/04/09	14	15	0.025	2.100	0.039	0.005K	0.020
73/04/24	14	25	0.015	0.440	0.008	0.005K	0.020
73/05/04	10	20	0.015	0.480	0.006	0.011	0.020
73/05/20	13	30	0.010K	0.630	0.006	0.007	0.025
73/06/11	10	55	0.010K	0.720	0.010	0.005K	0.020
73/07/13	15	35	0.010K	0.580	0.017	0.005K	0.015
73/08/17	14	10	0.010K	0.330	0.020	0.014	0.020
73/09/17	13	50	0.025	0.670	0.050	0.009	0.025

K VALUE KNOWN TO BE LESS
THAN INDICATED

22.

STORET RETRIEVAL DATE 74/10/10

273781 LS273781
46 23 00.0 094 22 00.0
LOWER GULL LK/DADE LAKE CONNECTI
27 CO #11, SHEET #1
T/GULL LAKE (CASS CO)
CO HWY 77 XING SW OF EAST GULL LAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	10	30	0.019	0.625	0.056	0.005K	0.014
72/11/18	13	50	0.017	0.760	0.062	0.005K	0.011
72/12/22	11	45	0.015	0.820	0.043	0.005K	0.015
73/01/06	10	00	0.014	0.840	0.048	0.005K	0.010
73/02/04	13	00	0.015	1.100	0.071	0.005K	0.010
73/03/26	14	30	0.020	1.760	0.078	0.010	0.020
73/04/09	14	00	0.010K	1.260	0.010	0.005K	0.020
73/04/24	13	30	0.010K	0.580	0.005K	0.005K	0.020
73/05/04	10	00	0.010K	0.665	0.005K	0.006	0.025K
73/05/20	10	00	0.010K	0.520	0.011	0.006	0.015
73/06/11	10	35	0.010K	0.790	0.009	0.005K	0.015
73/07/13	14	00	0.010K	0.700	0.014	0.005K	0.020
73/08/17	14	00	0.010K	0.660	0.030	0.020	0.030
73/09/17	13	00	0.010K	0.630	0.029	0.007	0.010

K VALUE KNOWN TO BE LESS
THAN INDICATED

23

STORET RETRIEVAL DATE 74/10/30

2737C1 LS2737C1
46 30 30.0 094 20 30.0
UPPER GULL LK/GULL LK CONNECTION
27 CO #11, SHEET #1
T/GULL LAKE (CASS CO)
CO HWY 77 BRDG AT VLG OF LAKE SHORE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	11	10	0.045	0.700	0.060	0.005K	0.026
72/11/18	14	30	0.065	0.580	0.056	0.006	0.021
72/12/22	10	00	0.115	0.560	0.048	0.005K	0.016
73/01/06	09	00	0.189	0.720	0.057	0.005K	0.020
73/02/04	14	00	0.252	0.540	0.027	0.005K	0.015
73/04/09	14	40	0.010K	1.000	0.011	0.008	0.050
73/04/24	14	00	0.082	0.660	0.032	0.005K	0.040
73/05/04	10	50	0.010K	0.640	0.005K	0.006	0.030
73/05/20	11	30	0.010K	0.650	0.008	0.007	0.025
73/06/11	11	20	0.010K	1.600	0.084	0.005K	0.020
73/07/13	15	00	0.010K	0.780	0.010	0.005K	0.025
73/08/17	14	30	0.010K	0.700	0.018	0.012	0.035
73/09/17	13	25	0.010K	0.720	0.024	0.008	0.025

K VALUE KNOWN TO BE LESS
THAN INDICATED

24.

STORET RETRIEVAL DATE 74/10/30

273701 LS273701
46 28 00.0 094 18 00.0
GULL LK/ROUND LK CONNECTION
27 CO #18, SHEET #2
T/GULL LAKE (CASS CO)
US HWY 371 XING
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	11 00		0.020	0.425	0.066	0.005K	0.015
72/11/18	14 15		0.010K	0.460	0.014	0.005K	0.008
72/12/22	10 30		0.010K	0.400	0.006	0.005K	0.012
73/01/06	09 30		0.010K	0.440	0.020	0.005K	0.015
73/02/04	13 45		0.010K	0.400	0.017	0.005K	0.005K
73/03/26	15 00		0.010K	1.000	0.046	0.007	0.010
73/04/09	14 30		0.010K	1.760	0.009	0.005K	0.010
73/04/24	14 00		0.010K	0.400	0.005K	0.005K	0.015
73/05/04	10 35		0.010K	0.580	0.005K	0.006	0.020
73/05/20	10 40		0.010K	0.540	0.005K	0.006	0.015
73/06/11	11 07		0.010K	1.100	0.010	0.005K	0.015
73/07/13	15 15		0.010K	0.540	0.009	0.005K	0.015
73/08/17	14 20		0.010K	0.500	0.016	0.008	0.020
73/09/17	13 35		0.010K	0.520	0.012	0.005K	0.015

K VALUE KNOWN TO BE LESS
THAN INDICATED

25.